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⑤④ **Method and apparatus for compensating CT images for truncated projections.**

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Description

This invention relates to a method and apparatus of compensating computed tomography (CT) images according to the first part of claims 1 and 10 respectively.

5 As disclosed in GB—A—2 009 560 or EP—A—0 030 143 it is necessary for a CT scanner to produce accurately reconstructed pictures that the body being examined be confined within the scanner's field of view and that accurate reference channel data be available. The reference channels, typically adjacent to the channels that measure attenuation data, serve as monitors of the incident radiation beam intensity. The field of view is the area, typically circular, about which the source, or source and detector, rotate to expose
10 the body and detect radiation from a plurality of angles around the body. If the body extends beyond the field of view, some of the measured projections are in error due to (a) shielding of the reference detectors thereby corrupting the reference channel information for some of the views and (b) failure to collect attenuation information concerning portions of the body extending beyond the field of view resulting in truncated views. For the former condition, the final image has low frequency shading resulting from
15 improper reference level shifting. For the latter condition artifacts manifest themselves typically as low spatial frequency shading or cupping, and sometimes also as streaks.

For some kinds of scans, it is simply not possible to obtain the desired slice while assuring that the body remains within the field of view. For example, when scanning the upper portion of the torso of large individuals, it may not be possible to assure that the shoulders remain within the field of view.

20 In view of the foregoing, it is an aim of the present invention to minimize artifacts in images created from truncated projection sets.

In accomplishing that aim, it is an object of the present invention to identify projections having faulty reference information, and to improve that reference information before normalization.

A further object of the invention is to identify truncated projection sets and complete those sets with
25 best estimate information derived from non-truncated sets. Finally, an object of the present invention is to accomplish the foregoing in an efficient manner which does not unacceptably increase the time needed to produce the CT image.

According to the invention as claimed the object is solved by the provisions of claims 1 and 10, respectively.

30 Further embodiments of the invention are claimed in the sub claims.

Other objects and advantages will become apparent from the following detailed description when taken in conjunction with the drawings, in which:

Figure 1 is a schematic view illustrating the major elements of a CT scanner;

Fig. 2 is a diagram illustrating an object extending beyond the field of view;

35 Fig. 3 is a flowchart illustrating the manner of improving reference channel information in accordance with the present invention;

Fig. 4 is a diagram illustrating a truncated projection set;

Fig. 5 illustrates the zeroeth and first order moments for a truncated projection set; and

Fig. 6 is a flowchart illustrating the completion of truncated projection sets in practicing the present
40 invention.

Turning now to the drawings, Fig. 1 schematically illustrates the major elements of a CT scanner. Note that a "rotate-only", or "third generation" scanner is shown for purposes of illustration, although the principles of this invention are not limited to such geometry. The scanner includes a source of penetrating radiation 10, very often in the form of a rotating anode X-ray tube. The radiation produced by the X-ray tube
45 10 is collimated at 11 to produce a thin fan beam of radiation 12 which is projected through a patient aperture 13 toward an X-ray detector array 14. A body to be examined, such as a patient 15, is positioned within the patient aperture 13 in the path of the fan beam of X-rays 12 such that the beam passing through the body is attenuated in dependence on the density of the objects encountered. As a result, each detector cell 14a, 14b, etc. produces an electrical signal which is dependent on the intensity of the radiation received
50 within the cell. The signals thus produced are therefore measures of the attenuation of the X-ray beam by the portion of the body through which it passed.

In operation, X-ray readings are taken from each cell at a plurality of angular positions with respect to the patient, as the source and detector array are rotated about the patient aperture. Each set of readings at a particular angle is often referred to as a projection or view. A typical view for one available scanner is made
55 up of 512 individual detector readings. Those readings for each view are digitized and fed to a reconstruction computer 16 which can use one of a number of available algorithms to produce the image of the cross section traversed by the fan beam. The image can be displayed on a CRT 17 or alternatively can be used to create a film for further study by a diagnostician.

A circle 20 within the patient aperture 13, and centered on the axis of rotation of the source and
60 detector, represents the field of view for the geometry illustrated in Fig. 1. If accurate reconstructions are to be made, the patient 15 must be confined within the field of view 20, in order to first of all get reliable reference channel information and secondly to produce non-truncated projections.

In the illustrated embodiment, the end detector cells 14x, 14y of the detector array are not used for determining attenuation of the patient, but instead are used to produce reference readings characteristic of
65 the unattenuated intensity of the X-ray source. Thus, it is important that radiation represented by the rays

21, 22, which pass through the patient aperture 13, but outside the field view 20, impinge on the cells 14x, 14y without interference. It is those readings which are used in the reconstruction computer 16 to normalize the readings from the remainder of the fan generally indicated at 23.

Fig. 2 diagrammatically illustrates the problem. The field of view 20 is illustrated along with a body to be examined 15 having a portion 15a within the field of view, but portions 15b, 15c extending beyond that field. A pair of projections are illustrated at 25, 26. It is seen that the projection 25 is "normal" in that the reference rays 21 and 22 pass the field of view 20 unobstructed for receipt by their associated detector cells. Similarly, the entire body 15 is scanned in that the entire body passes radiation which will be detected.

However, the view 26 illustrates a projection which is truncated in two ways. First of all, both of the reference beams 21, 22 pass through the body such that the readings of the reference channels 14x, 14y will not be a true measure of the unattenuated intensity of the X-ray source for that view. Secondly, the attenuation of the entire body is not measured in view 26 because portions 15b and 15c are not within the field of view and, even if they were exposed to X-rays, those X-rays would not be detected. Thus, for the view 26, the scanner acts as if it were measuring a different body comprising only the section 15a.

The effect of the two conditions noted above can have a serious effect on the CT image if it were simply processed in the normal way. First of all, the obscuring of the reference channels for some of the projections causes each of those obscured projections to include a uniform d.c. shift. Such a d.c. shift tends to produce low frequency shading in any reconstruction made using the obscured projections. We have found that the d.c. shift caused simply by obscuring the reference channels can be on the order of 70 H.U. in typical clinical cases, a significant quantity.

In practicing the invention, the d.c. shift of the logarithmic projections for truncated views in which the reference channels were obscured is substantially reduced by identifying each view having obscured reference channel information and replacing it with better information derived from non-truncated projections. The manner in which that is accomplished is best explained with reference to Fig. 3, which illustrates a sequence of steps carried out within the apparatus of Fig. 1.

After starting the procedure at step 30, the apparatus is first cycled at step 31 to produce a projection or view for each angle θ as the source and detector rotate through a range of θ 's around the patient. Scanners are available which can produce about 511 readings for each projection, and take approximately 576 projections as the source and detector rotate about the body. Each of those projections has reference cell intensity information associated therewith, referred to as I_r in Fig. 3. Having produced all the projections at step 31, the system cycles to a step 32 which searches through each projection for the maximum intensity among all the reference channel information. Having acquired that maximum intensity information, the system determines a threshold intensity I_T which is some fraction of the maximum intensity. Each reference intensity is then compared with the threshold so that the system can make a determination as to whether the reference channel for any view was likely obscured. As noted at 34, the first view is selected and at 35 the reference channel information obtained for that view. At step 36, the reference channel information is compared to the threshold intensity. If the reference channel is found to be below the threshold, a step 37 is used to flag that projection for later operation. If, on the contrary, the reference channel information is above the threshold, it is concluded that the view was made with unobscured reference channels. In that event, the intensity information is stored at a step 38 and an index incremented at 39 to produce typical reference information for later use. A step 40 is then used to select the next view and the procedure repeated. In each case, the view is either flagged at 37 or added to the summation at 38, depending on its relationship to the threshold intensity. After all views have been processed, a step 41 calculates a typical intensity, in the illustrated embodiment an average intensity, for the good views by dividing the summed intensity values by the number of values so summed. The program then at step 42 retrieves in turn each view or projection which had been flagged at step 37 and, for each of those views at step 43 replaces the reference intensity information with the average information calculated in step 41.

Having accomplished that for all views, the best reference channel information is then available and a step 44 can be accomplished to normalize each view in the conventional fashion.

We have found that processing the reference channel information in this way has proven to correct an error of about 70 H.U. by more than 50 H.U., thus proving to be of worthwhile benefit. A large part of the remaining error is due to the second type of aberration discussed above, namely, the presence of views in which portions of the body did not contribute to the projection set. That aspect of the problem can best be illustrated with reference to Fig. 4.

Fig. 4 represents a plot of the measured logarithmic attenuation values for a view or projection. The amplitude is plotted along the vertical axis, and detector position within the fan is plotted as ϕ along the horizontal axis. The central detector is illustrated in the center of the array at $\phi=0$. The plot is intended to illustrate a truncated view in that the detector itself encompasses only the fan angles from ϕ_1 to ϕ_2 , $p_m(\phi)$ connoting values resulting from detector readings. The projection set is illustrated as extending beyond ϕ_1 and ϕ_2 to ϕ'_1 and ϕ'_2 , respectively, and the functions $g_1(\phi)$ and $g_2(\phi)$ connote a truncated projection set. Recalling that the body portions 15b, 15c of Fig. 2 projected beyond the field of view, it will be appreciated that the $g_1(\phi)$ and $g_2(\phi)$ portions of the projection set have been lost. Thus, all the information derived in collecting the projection in question is represented by $p_m(\phi)$ and if that were convolved in the normal way, the fact that the $g_1(\phi)$ and $g_2(\phi)$ information was neglected would produce artifacts in the resulting image.

It is known that when the projections are truncated as in Fig. 4, that is, only the $p_m(\phi)$ information is

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available, it is impossible to uniquely reconstruct the object. However, if a reasonable number of the projections (say at least half) are not truncated, it is possible to make a reasonable estimate of the low spatial-frequency features of the "completion functions", the $g(\phi)$, and use that best estimate completed projection for further processing.

5 In practicing the invention, a plurality of moments of the projections, in the illustrated embodiment the zeroeth and first order moments, both truncated and non-truncated, are used to determine the degree of truncation, and to apportion the truncated information to the correction functions using, for each view, in addition to the moments, only information within the view in question.

Turning to Fig. 6A, it is seen that the system starts operation at 70, and first produces a projection set including all angles θ at step 71, in the manner described above. Step 72 is used to follow the entire procedure of Fig. 3 in removing the effects of obscured reference channels. Step 73 is then executed to determine the zeroeth and first order moments, Q_0 and Q_1 for each projection within the set. Digressing to Fig. 5, the nature of the moment of a projection set will briefly be discussed. The equation for calculating a moment is:

15

$$Q_k = \int_{\phi'_1}^{\phi'_2} p(\phi) \phi^k d\phi, \quad k=0,1 \quad (1)$$

20 where Q is the moment, k is an index indicating its order, and the remaining variables have been previously identified. Thus, the zeroeth order moment is in the nature of an integration of the amplitudes in the projection $p(\phi)$ and can be thought of as relating to the total "mass" within the projection. Since that mass doesn't change greatly if the entire object stays within the field of view, the zeroeth order moment should remain fairly constant for all views. For parallel beam geometry, the zeroeth order moment is indeed a constant whereas in the fan beam geometry illustrated in Fig. 1, the zeroeth order moment 55 can be a sinusoidal-like function with no more than one cycle across the set, and having relatively low amplitude. The first order moment is illustrated at 56, and can be conceptualized as related to the location of the centroid of the mass represented by the zeroeth order moment. Like the zeroeth order moment, it can vary with angle, but with only two full periods per 360 degree projection set.

30 In accordance with the invention, the moment information discussed above is examined to detect variations from expected behavior, to identify the views producing such variation as truncated, to estimate more likely moments for completed views, and to utilize that information in completing the truncated projections. Fig. 5 illustrates two areas where the moments behave in an unexpected fashion, those areas being bracketed at 57 and 58. It is seen that in the area 57, the amplitude of the zeroeth order moment Q_0 increases in an unexpected fashion and the initially well behaved first order moment Q_1 shows an unexpected undulation. Thus, each view encompassed within the area 57 can be said to be truncated, and expected moments should be determined to compare with the actual ones for the purpose of completing the views. Thus, for the zeroeth order moment, the more or less straight line segment 60 is determined to be a better estimate of what the moment of the completed data set would have been, and the straight line section 61 estimated to be a more likely first order moment for the area if the projection set had been complete. Similar criteria lead to the identification of the views bracketed at 58 as being truncated, and in the estimation of straight line 62 as a more likely zeroeth order moment and straight line 63 as a more likely first order moment for the area had the views been complete. While it is convenient to use straight lines, other curves could be used if desired.

45 Returning to Fig. 6, the step 74 performs the identification of the areas 57 and 58 and flags each view within those bracketed areas. The step 75 then determines what the moments would likely have been had the projection sets been complete as discussed above. Having made those determinations, the system then returns to each flagged view and, using the moment information detailed, above along with the information in that view, then completes the view by determining extension functions (the $g(\phi)$'s of Fig. 4). The latter is accomplished by fitting low order polynomials to the available information. The order of the polynomials chosen to represent $g_i(\phi)$ determines the number of constraints which must be formulated. That number in turn determines the number of moments which must be calculated in the formulation. The particular embodiment described here uses first-order polynomials (i.e., straight lines), for which only Q_0 and Q_1 need be considered.

55 In order to determine the coefficients of the particular low order polynomials, a first constraint is placed on the extended projection set, requiring at some point that its amplitude go to zero. That is likened to the physical requirement of the body ending at some point. Fig. 4 illustrates the points ϕ'_1 and ϕ'_2 at which the extended projection set goes to zero. The actual location of ϕ'_1 and ϕ'_2 must still be determined.

60 An additional two constraints are placed on the function using the zeroeth and first order moments. Having determined best estimate values for those moments above, and knowing the actual moments for the truncated projection sets, the requirement is that the measured moments be altered to conform with the expected moments.

A final constraint found useful is that of continuity of the projection and its derivatives across boundaries between the truncated projection set and the extended projection set. That can be stated as the derivative of some order of g_i with respect to ϕ be equal to the derivative of p_i with respect to ϕ at ϕ_1 and

ϕ_2 . The order of the derivatives required for this constraint is determined by the order of the polynomial. If a first order polynomial, i.e., a straight line, is chosen, then it is only necessary to insure that the completed projection is continuous at the boundary. Continuity can be accomplished by simply assigning the amplitude of the last point in the truncated set, p_1 or p_2 , to the first point in the extended set g_1 or g_2 , respectively.

Turning to Figs. 6A and 6B, it is seen that the steps 76, 77 serve to obtain the first truncated view (that which would correspond to $p_m(\phi)$ of Fig. 4). The step 78 is then accomplished as described generally above to set the value of the first point in the extended projection set to that of the last point in the truncated projection set at each end of the set. The points where that operation is accomplished are illustrated at 79, 80 of Fig. 4.

The system then proceeds to a step 82 which determines the amount of mass which was truncated by using the zeroeth order moment information. More particularly, recalling Fig. 5, and assuming the system is operating on a view within the bracketed portion 57, the system would determine the difference between the estimated zeroeth order moment 60 and the corresponding measured moment from the truncated data.

Step 83 is then performed to determine the centroid of the total amount of mass in the extended projection set using the first order moment information from step 75. The physical significance of that can be appreciated with respect to Fig. 4. Recalling that the points 80 and 81 are known, the step 82 determines the total area under the curves $g_1(\phi)$ and $g_2(\phi)$. In order to further define those functions, the step 83 determines where the center of mass for the entire projection set should be, and from that information the area under the curves $g_1(\phi)$ and $g_2(\phi)$ can be apportioned. That is accomplished in a step 85 by fitting a low order polynomial to the extended projection set, thus defining in the illustrated embodiment $g_1(\phi)$ and $g_2(\phi)$ by requiring them to be straight lines, and by determining their slope and intercept. A step 86 then selects the next truncated projection and repeats the entire procedure. The end result is the completion of each truncated projection with estimated data most likely to satisfy at least the low frequency continuity requirements of the reconstruction algorithm.

The manipulative steps set out in connection with Figs. 6A and 6B can also be described mathematically, and a discussion thereof will be provided as an aid in programming the reconstruction computer to perform the method according to the present invention. First of all, the straight line to be defined for the extended function, $g_i(\phi)$ or $g_2(\phi)$, or generally $g_i(\phi)$ where i is 1 or 2, can be defined as:

$$g_i(\phi) = a_i\phi + b_i \quad (2)$$

The coefficients a_i and b_i are to be determined in order to define the function. The continuity of the projection requires that:

$$g_i(\phi_i) = p_m(\phi_i) \equiv p_i \quad (3)$$

which states mathematically that the truncated curve connects smoothly with the extended curve at the points 80 and 81 of Fig. 4. It follows from that requirement that the value of ϕ_i at amplitude is defined by:

$$\phi'_i = -b_i/a_i \quad (4)$$

With that in mind, equation (3) can be rewritten as:

$$g_i(\phi) = a_i(\phi - \phi_i) + p_i \quad (5)$$

In addition, a function δ_i can be defined, relating to the horizontal coordinate of the extension function ($\phi'_i - \phi_i$), and that can be set equal to the intercept and slope as set out in equation 4 yielding the following:

$$\delta_i = \phi'_i - \phi_i = -p_i/a_i \quad (6)$$

The steps 82 and 83 of Fig. 6 can be described mathematically by the following expression:

$$R_k \equiv Q_k - \int_{\phi_1}^{\phi_2} p_m(\phi) \phi^k d\phi = \int_{\phi'_1}^{\phi_1} g_1(\phi) \phi^k d\phi + \int_{\phi_2}^{\phi'_2} g_2(\phi) \phi^k d\phi \quad (7)$$

where the expression generally applies to moments of all orders, but the zeroeth and first order moments are utilized by setting the index k equal to zero and 1. The quantity R_k is the difference between the moment of the truncated set and the expected moment had the set been complete. The quantity Q_k represents the latter, whereas the integral of p_m between the limits of ϕ_1 and ϕ_2 represents the measured moment from the truncated data set. That difference is the quantity which must be divided between the extension functions, as set out for the $g_1(\phi)$ and $g_2(\phi)$ integrals over the extended function.

Equation 18 can be manipulated to yield a form more adaptable to utilizing the moment and view information in determining the coefficients of the extended function. After some manipulation, and utilizing both the zeroth and first order moments, equation 7 leads to:

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$$\frac{p_1^2}{2} \xi_1 - \frac{p_2^2}{2} \xi_2 = R_0 \quad (8)$$

$$\frac{\phi_1 p_1^2}{2} \xi_1 - \frac{p_1^3}{6} \xi_1^2 - \frac{\phi_2 p_2^2}{2} \xi_2 + \frac{p_2^3}{6} \xi_2^2 = R_1 \quad (9)$$

$$\xi_i \equiv 1/a_i \quad (10)$$

Elimination of ξ_1 leads to:

$$v_1 \xi_1^2 + v_2 \xi_2 + v_3 = 0 \quad (11)$$

where:

$$v_1 = \frac{p_2^3}{6} (1 - p_2/p_1) \quad (12)$$

$$v_2 = \frac{p_2^2}{2} \left(\phi_1 - \phi_2 - \frac{4}{3} \frac{R_0}{p_1} \right)$$

$$v_3 = -R_1 + \phi_1 R_0 - \frac{2}{3} \frac{R_0^2}{p_1}$$

Using the conventional formula for solution of a quadratic, and solving equation 11 for ξ_2 yields:

$$\xi_2 = \{-V_2 - \sqrt{V_2^2 - 4V_1V_3}\} / 2V_1 \quad (13)$$

finally, using ξ_2 to solve for ξ_1 , the inverse of the slope of the extended function, yields:

$$\xi_1 = \frac{p_2^2}{p_1^2} \xi_2 + \frac{2R_0}{p_1^2} \quad (14)$$

Having first determined the actual truncated moments and expected moments had the projection in question not been truncated, it will now be apparent that any view can be accessed and completed simply using the moment information and the data from the view in question. First of all, it is first necessary to use the amplitudes of the points 80 and 81 (Fig. 4) identified as p_1 and p_2 , the zero and first order moments R_0 and R_1 , and the channel angle at truncation ϕ_1 and ϕ_2 to compute the coefficients set out in equation 12. Those coefficients are then used in equation 13 to calculate ξ_2 following which ξ_2 is used in equation 14 to calculate ξ_1 . The intercepts are provided by equation 4, and using only the information within that view, the coefficients for the functions $g_1(\phi)$ and $g_2(\phi)$ are determined to complete the truncated data set.

It is noted that a special case can exist where the projection is truncated on only one side. In that case, it is only necessary to apply equation 3 and the first moment Equation (7) to find the slope. In the case where the left end of the projection is missing, the inverse of the slope is determined by:

$$\xi_1 = 2R_0/p_1^2 \quad (15)$$

while for the right end:

$$\xi_2 = -2R_0/p_2^2 \quad (16)$$

Thus, the coefficients of the two extension functions are completely determined, and in combination with the original truncated projection defines an extended projection which will satisfy at least the low frequency continuity requirements of the reconstruction algorithm.

It is then possible to use that extended function by convolving it with the standard convolution filter to produce a filtered data set used in back projection to reconstruct an image. However, in many modern CT scanners, convolution is performed in the Fourier domain, first using a Fast Fourier Transform followed by a multiplication and an inverse transform before back projection.

In a particular CT scanner, a 1024 point FFT is used on non-truncated data sets having about 511 elements to avoid wrap-around. It is thus not unlikely to assume that extending a projection set as described above will increase the data set such that a 1024 point FFT will not be sufficient. To use standard convolution techniques for that extended data set would therefore require at least a 2048 point FFT, approximately doubling the time necessary to make the transform.

In accordance with a particular aspect of the invention, that difficulty is avoided by using conventional FFT convolution for the non-truncated portion of the data set and using an approximate closed form

solution for the extended portion, then combining the two convolutions to produce a modified projection set for back projection. Thus, returning to Fig. 6B, a step 90 convolves each of the measured projection sets whether truncated or not. Then, a step 91 selects each of the truncated sets and performs a closed form solution for convolution of the extension. A step 92 then combines that closed form convolution with the
5 FFT convolution of step 90 for each truncated projection set in order to produce a more accurate set of filtered data taking into account the body portions beyond the field of view. The step 93 then performs the normal procedures used for producing an image, typically back projection.

The convolution of the extended portion, which it is desired to evaluate can be set out as follows:

$$10 \quad q_1(\phi) = [g_1(\phi) \cos \phi] * K(\phi), \quad \phi_1 < \phi < \phi_2 \quad (17)$$

where $K(\phi)$ is the kernel, and the expression need only be evaluated within the field of view, that is, between ϕ_1 and ϕ_2 . When a specific kernel is chosen, in the present example that which has come to be known as the LAKS kernel, equation 17 can be evaluated in closed form. First of all, it can be approximated
15 as:

$$q_1(\phi) = \cos \phi [g_1(\phi) * K(\phi)] \quad (18)$$

Then for:

$$20 \quad g_2(\phi) = p_2 \left(1 - \frac{\phi - \phi_2}{\delta_2} \right) \quad (19)$$

the Fourier transform is:

$$25 \quad G_2(k) = p_2 e^{-ik\phi_2} \left\{ \frac{1 - \cos k \delta_2}{k^2 \delta_2} + i \left(\frac{\sin k \delta_2}{k^2 \delta_2} - \frac{1}{k} \right) \right\} \quad (20)$$

Thus, for the LAKS kernel the convolution can be stated as:

$$30 \quad g_2'(\phi) = \frac{g_2(\phi)}{p_2 \cos \phi_2} = \frac{1}{2\pi} \int_{-\infty}^{\infty} |k| G_2(k) e^{ik\phi} dk \quad (21)$$

35 and can be solved as:

$$40 \quad g_2(Q) = \frac{1}{\pi \delta_2} \log \left[\frac{\delta_2 + \phi_2 - \phi}{\phi_2 - \phi} \right] - \frac{1}{\pi(\phi_2 - \phi_1)} \quad (22)$$

for the limits within the field of view. A similar expression can be calculated for q_1 , evaluating the effect on the convolution of the area outside the field of view on the elements within the field of view.

The use of "LAKS" kernel for fan-beam geometry is not strictly valid. We have found that the error so produced is negligible inasmuch as only low spatial frequencies are recovered by the extension process.

45 Experimentation with the procedures described herein, in which the first two moments of the extended projections are made consistent with the other views, has shown that shading artifacts caused by truncated views can be significantly reduced. Furthermore, using the closed form solution for evaluation of the convolution of the extensions of the projection sets accomplishes that result without an unacceptable increase in processing time.

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Claims

1. A method of compensating a CT image wherein a body is exposed to radiation at a plurality of angles about the body, detecting radiation passing through the body at the plurality of angles to create a set of
55 projections in which some of said projections are affected by the body extending beyond the field of view, and each of said projections has reference channel information associated therewith characterized by the steps of detecting reference channel information below a predetermined level to identify the projections having reference channel information affected by the object, determining a typical reference channel level from the unaffected projections, assigning the typical reference channel level to the reference channels of
60 said identified projections, normalizing each projection with the reference level assigned thereto, and producing an image from the normalized projection set.

2. The method according to claim 1 characterized by the steps of finding the maximum reference channel level within the projection set, identifying each projection having a reference channel level which is a predetermined amount less than said maximum level thereby, to identify the projections having
65 reference channel information affected by the object, determining a typical value of reference channel level

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for projections not identified, replacing the reference channel level in the identified projections with said typical value, normalizing each projection with respect to the reference level assigned thereto, and producing an image from the modified projection set.

3. The method according to claim 1 or claim 2 in which some of the projections are truncated, further
5 characterized by the steps of determining the zeroeth and first order moments of the projection set, determining from the zeroeth order moment the amount of missing mass from the truncated projections, determining from the first order moments the centroid of an extended projection relating to each truncated projection, using the missing mass and centroid information for each truncated projection to extend said projection, convolving each projection to produce a convolved projection set, and producing an image
10 from the convolved projection set.

4. The method according to claim 3 characterized in that the step of convolving includes using a Fast Fourier Transform to convolve each untruncated projection and the non-truncated portion of each truncated projection, using a closed form solution to convolve the extended portions of the truncated projections, and combining the closed form solution with the convolution for each truncated projection set.

15 5. The method according to any one of claims 1 to 4 characterized by the steps of determining a plurality of moments of the projection set, determining from the moments the amount of mass missing from each truncated projection and the distribution of the missing mass in each truncated projection, fitting a low order polynomial conforming with the moments and boundary conditions to extend each truncated projection, convolving each projection with a kernel to produce a convolved projection set and producing
20 an image from the convolved projection set.

6. The method according to claim 5 characterized by the step of determining a plurality of moments includes determining the zeroeth and first order moments, the step of determining the amount of missing mass uses the zeroeth order moment, and determining the distribution of the missing mass uses the first order moment.

25 7. The method according to claim 5 characterized by the step of convolving includes using a Fast Fourier Transform to convolve each untruncated projection and the non-truncated portion of each truncated projection, using a closed form solution to convolve the extended portions of the truncated projections, and combining the closed form solution with the convolution for each truncated projection.

8. The method according to any one of claims 5, 6 or 7 characterized by the step of fitting a low order
30 polynomial includes starting the extended portion at a point smoothly merging into the non-truncated portion of the projection, using the zeroeth and first order moments to fit the low order polynomial between the starting point and a point at which the extended projection becomes zero.

9. The method according to claim 8 characterized in that the low order polynomial is a first order polynomial.

35 10. An apparatus for compensating a CT image wherein a body (15) is exposed to radiation at a plurality of angles about the body, comprising means (14) for detecting radiation passing through the body at the plurality of angles to create a set of projections in which some of said projections are affected by the body extending beyond the field of view, and each of said projections has reference channel information (21, 22) associated therewith, characterized by means (32, 33, 36) for detecting reference channel
40 information below a predetermined level to identify the projections having reference channel information affected by the object, means (41) for determining a typical reference channel level from the unaffected projections, means (43) for assigning the typical reference channel level to the reference channels of said identified projections, means (44) for normalizing each projection with the reference level assigned thereto, and means (16, 17) for producing an image from the normalized projection set.

45 11. The apparatus according to claim 10 characterized by means (32) for finding the maximum reference channel level within the projection set, means (33, 36) for identifying each projection having a reference channel level which is a predetermined amount less than said maximum level thereby, to identify the projections having reference channel information affected by the object, means (41) for determining a typical value of reference channel level for projections not identified, means (43) for replacing the reference
50 channel level in the identified projections with said typical value, means (44) for normalizing each projection with respect to the reference level assigned thereto, and means (16, 17) for producing an image from the modified projection set.

12. The apparatus according to claim 10 or claim 11 in which some of the projections are truncated, further characterized by means (73) for determining the zeroeth and first order moments of the projection
55 set, means (82) for determining from the zeroeth order moment the amount of missing mass from the truncated projections, means (83) for determining from the first order moments the centroid of an extended projection relating to each truncated projection, means (84, 85) for using the missing mass and centroid information for each truncated projection to extend said projection, means (90—92) for convolving each projection to produce a convolved projection set, and means (93) for producing an image from the
60 convolved projection set.

13. The apparatus according to claim 12 characterized in that the means for convolving includes means (90) for using a Fast Fourier Transform to convolve each untruncated projection and the non-truncated portion of each truncated projection, means (91) for using a closed form solution to convolve the extended portions of the truncated projections, and means (92) for combining the closed form solution with the
65 convolution for each truncated projection set.

14. The apparatus according to any one of claims 10 to 13 characterized by means (73) for determining a plurality of moments of the projection set, means (82, 83) for determining from the moments the amount of mass missing from each truncated projection and the distribution of the missing mass in each truncated projection, means (85) for fitting a low order polynomial conforming with the moments and boundary
5 conditions to extend each truncated projection, means (90—92) for convolving each projection with a kernel to produce a convolved projection set and means (93) for producing an image from the convolved projection set.

15. The apparatus according to claim 14, characterized by the means for determining a plurality of moments includes means (73) for determining the zeroeth and first order moments, the means (82) for
10 determining the amount of missing mass uses the zeroeth order moment, and the means (83) for determining the distribution of the missing mass uses the first order moment.

16. The apparatus according to claim 14, characterized by the means for convolving includes means (90) for using a Fast Fourier Transform to convolve each untruncated projection and the non-truncated portion of each truncated projection, means (91) for using a closed form solution to convolve the extended
15 portions of the truncated projections, and means (92) for combining the closed form solution with the convolution for each truncated projection.

17. The apparatus according to any one of claims 14 to 16 characterized by the means (85) for fitting a low order polynomial includes means for starting the extended portion at a point smoothly merging into the non-truncated portion of the projection, means for using the zeroeth and first order moments to fit the
20 low order polynomial between the starting point and a point at which the extended projection becomes zero.

18. The apparatus according to claim 17 characterized in that the low order polynomial is a first order polynomial.

25 Patentansprüche

1. Verfahren zum Kompensieren eines CT-Bildes, wobei ein Körper an mehreren Winkeln um den Körper herum Strahlung ausgesetzt wird, an den mehreren Winkeln die durch den Körper hindurchtretende Strahlung detektiert wird, um einen Satz von Projektionen zu erzeugen, in dem einige der Projektionen
30 durch den Körper beeinflusst werden, der sich über das Betrachtungsfeld erstreckt, und jeder Projektion eine Referenzkanalinformation zugeordnet ist, gekennzeichnet durch Schritte zum Detektieren der Referenzkanalinformation unterhalb eines vorbestimmten Pegels, um die Projektionen mit Referenzkanalinformation zu identifizieren, die durch den Gegenstand beeinflusst sind, Bestimmen eines typischen Referenzkanalpegels aus den unbeeinflussten Projektionen, Zuordnen des typischen Referenzkanalpegels
35 zu den Referenzkanälen der identifizierten Projektionen, Normieren jeder Projektion mit dem zugeordneten Referenzpegel und Erzeugen eines Bildes aus dem normierten Projektionssatz.

2. Verfahren nach Anspruch 1, gekennzeichnet durch Schritte zum Finden des maximalen Referenzkanalpegels innerhalb des Projektionssatzes, Identifizieren jeder Projektion mit einem Referenzkanalpegel, der einen vorbestimmten Betrag kleiner als der maximale Pegel ist, um dadurch die
40 Projektionen mit Referenzkanalinformation zu identifizieren, die durch den Gegenstand beeinflusst sind, Bestimmen eines typischen Wertes des Referenzkanalpegels für nicht identifizierte Projektionen, Ersetzen des Referenzkanalpegels in den identifizierten Projektionen gegen den typischen Wert, Normieren jeder Projektion in bezug auf den zugeordneten Referenzpegel und Erzeugen eines Bildes aus dem modifizierten Projektionssatz.

3. Verfahren nach Anspruch 1 oder 2, wobei einige der Projektionen abgeschnitten sind, gekennzeichnet durch Schritte zum Bestimmen der Momente nullter und erster Ordnung des Projektionssatzes, Bestimmen der Größe der fehlenden Masse von den abgeschnittenen Projektionen aus dem Moment nullter Ordnung, Bestimmen des Massezentrums einer verlängerten Projektion in Relation zu
50 jeder abgeschnittenen Projektion aus den Momenten erster Ordnung, Verwenden der sich auf die fehlende Masse und das Massenzentrum beziehenden Information für jede abgeschnittene Projektion, um die Projektion zu verlängern, Falten jeder Projektion, um einen gefalteten Projektionssatz zu erzeugen, und Erzeugen eines Bildes aus dem gefalteten Projektionssatz.

4. Verfahren nach Anspruch 3, dadurch gekennzeichnet, daß der Schritt zum Falten das Verwenden einer schnellen Fourier-Transformation (FFT), um jede nicht abgeschnittene Projektion und den nicht abgeschnittenen Teil jeder geschnittenen Projektion zu falten, Verwenden einer Lösung geschlossener Form, um die verlängerten Abschnitte der geschnittenen Projektionen zu falten, und Vereinigen der Lösung geschlossener Form mit der Faltung für jeden geschnittenen Projektionssatz enthält.

5. Verfahren nach einem der Ansprüche 1 bis 4, gekennzeichnet durch Schritte zum Bestimmen von mehreren Momenten des Projektionssatzes, Bestimmen der Größe der fehlenden Masse aus jeder geschnittenen Projektion und der Verteilung der fehlenden Masse in jeder geschnittenen Projektion aus den Momenten, Anpassen eines Polynoms niedriger Ordnung, das mit den Momenten und Randbedingungen übereinstimmt, um jede geschnittene Projektion zu verlängern, Falten jeder Projektion mit einem Kern, um einen gefalteten Projektionssatz zu erzeugen, und Erzeugen eines Bildes aus dem gefalteten Projektionssatz.

6. Verfahren nach Anspruch 5, dadurch gekennzeichnet, daß der Schritt zum Bestimmen mehrerer

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Momente die Bestimmung der Momente nullter und erster Ordnung aufweist, der Schritt zur Bestimmung der Größe der fehlenden Masse das Moment nullter Ordnung verwendet und die Bestimmung der Verteilung der fehlenden Masse das Moment erster Ordnung verwendet.

7. Verfahren nach Anspruch 5, dadurch gekennzeichnet, daß der Schritt zum Falten das Verwenden einer schnellen Fourier-Transformation (FFT), um jede nicht geschnittene Projektion und den nicht geschnittenen Teil jeder geschnittenen Projektion zu falten, Verwenden einer Lösung geschlossener Form, um die verlängerten Teile der geschnittenen Projektionen zu falten, und Vereinigen der Lösung geschlossener Form mit der Faltung für jede geschnittene Projektion enthält.

8. Verfahren nach einem der Ansprüche 5, 6 oder 7, dadurch gekennzeichnet, daß der Schritt zum Anpassen eines Polynoms niedriger Ordnung das Beginnen des verlängerten Teils an einem Punkt, der glatt in den nicht geschnittenen Teil der Projektion übergeht, und das Verwenden der Momente nullter und erster Ordnung enthält, um das Polynom niedriger Ordnung zwischen dem Anfangspunkt und einem Punkt anzupassen, an dem die verlängerte Projektion Null wird.

9. Verfahren nach Anspruch 8, dadurch gekennzeichnet, daß das Polynom niedriger Ordnung ein Polynom erster Ordnung ist.

10. Vorrichtung zum Kompensieren eines CT-Bildes, wobei ein Körper (15) an mehreren Winkeln um den Körper herum Strahlung ausgesetzt wird, mit Mitteln (14) zum Detektieren von Strahlung, die an mehreren Winkeln durch den Körper hindurchtritt, um einen Satz von Projektionen zu erzeugen, in dem einige der Projektionen durch den Körper beeinflusst werden, der sich über das Betrachtungsfeld erstreckt, und jeder Projektion eine Referenzkanalinformation (21, 22) zugeordnet ist, gekennzeichnet durch Mittel (32, 33, 36) zum Detektieren der Referenzkanalinformation unterhalb eines vorbestimmten Pegels, um die Projektionen mit Referenzkanalinformation zu identifizieren, die durch den Gegenstand beeinflusst sind, Mittel (41) zum Bestimmen eines typischen Referenzkanalpegels aus den unbeeinflussten Projektionen, Mittel (43) zum Zuordnen des typischen Referenzkanalpegels zu den Referenzkanälen der identifizierten Projektionen, Mittel (44) zum Normieren jeder Projektion mit dem zugeordneten Referenzpegel und Mittel (16, 17) zum Erzeugen eines Bildes aus dem normierten Projektionssatz.

11. Vorrichtung nach Anspruch 10, gekennzeichnet durch Mittel (32) zum Finden des maximalen Referenzkanalpegels innerhalb des Projektionssatzes, Mittel (33, 36) zum Identifizieren jeder Projektion mit einem Referenzkanalpegel, der einen vorbestimmten Betrag kleiner als der maximale Pegel ist, um dadurch die Projektionen mit Referenzkanalinformation zu identifizieren, die durch den Gegenstand beeinflusst sind, Mittel (41) zum Bestimmen eines typischen Wertes des Referenzkanalpegels für nicht identifizierte Projektionen, Mittel (43) zum Ersetzen des Referenzkanalpegels in den identifizierten Projektionen gegen den typischen Wert, Mittel (44) zum Normieren jeder Projektion in bezug auf den zugeordneten Referenzpegel und Mittel (16, 17) zum Erzeugen eines Bildes aus dem modifizierten Projektionssatz.

12. Vorrichtung nach Anspruch 10 oder 11, wobei einige der Projektionen abgeschnitten sind, gekennzeichnet durch Mittel (73) zum Bestimmen der Momente nullter und erster Ordnung des Projektionssatzes, Mittel (82) zum Bestimmen der Größe der fehlenden Masse von den abgeschnittenen Projektionen aus dem Moment nullter Ordnung, Mittel (83) zum Bestimmen des Massezentrums einer verlängerten Projektion in Relation zu jeder abgeschnittenen Projektion aus den Momenten erster Ordnung, Mittel (84, 85) zum Verwenden der sich auf die fehlende Masse und das Massenzentrum beziehenden Information für jede abgeschnittene Projektion, um die Projektion zu verlängern, Mittel (90—92) zum Falten jeder Projektion, um einen gefalteten Projektionssatz zu erzeugen, und Mittel (93) zum Erzeugen eines Bildes aus dem gefalteten Projektionssatz.

13. Vorrichtung nach Anspruch 12, dadurch gekennzeichnet, daß die Mittel zum Falten Mittel (90) zum Verwenden einer schnellen Fourier-Transformation (FFT), um jede nicht abgeschnittene Projektion und den nicht abgeschnittenen Teil jeder geschnittenen Projektion zu falten, Mittel (91) zum Verwenden einer Lösung geschlossener Form, um die verlängerten Abschnitte der geschnittenen Projektionen zu falten, und Mittel (92) zum Vereinigen der Lösung geschlossener Form mit der Faltung für jeden geschnittenen Projektionssatz enthalten.

14. Vorrichtung nach einem der Ansprüche 10 bis 13, gekennzeichnet durch Mittel (73) zum Bestimmen von mehreren Momenten des Projektionssatzes, Mittel (82, 83) zum Bestimmen der Größe der fehlenden Masse aus jeder geschnittenen Projektion und der Verteilung der fehlenden Masse in jeder geschnittenen Projektion aus den Momenten, Mittel (85) zum Anpassen eines Polynoms niedriger Ordnung, das mit den Momenten und Randbedingungen übereinstimmt, um jede geschnittene Projektion zu verlängern, Mittel (90—92) zum Falten jeder Projektion mit einem Kern, um einen gefalteten Projektionssatz zu erzeugen, und Mittel (93) zum Erzeugen eines Bildes aus dem gefalteten Projektionssatz.

15. Vorrichtung nach Anspruch 14, dadurch gekennzeichnet, daß die Mittel zum Bestimmen mehrerer Momente Mittel (73) zum Bestimmen der Momente nullter und erster Ordnung aufweisen, die Mittel (82) zum Bestimmen der Größe der fehlenden Masse das Moment nullter Ordnung verwenden und die Mittel (83) zum Bestimmen der Verteilung der fehlenden Masse das Moment erster Ordnung verwenden.

16. Vorrichtung nach Anspruch 14, dadurch gekennzeichnet, daß die Mittel zum Falten Mittel (90) zum Verwenden einer schnellen Fourier-Transformation (FFT), um jede nicht geschnittene Projektion und den nicht geschnittenen Teil jeder geschnittenen Projektion zu falten, Mittel (91) zum Verwenden einer Lösung geschlossener Form, um die verlängerten Teile der geschnittenen Projektionen zu falten, und Mittel (92) zum Vereinigen der Lösung geschlossener Form mit der Faltung für jede geschnittene Projektion enthalten.

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17. Vorrichtung nach einem der Ansprüche 14 bis 16, dadurch gekennzeichnet, daß Mittel (85) zum Anpassen eines Polynoms niedriger Ordnung Mittel zum Beginnen des verlängerten Teils an einem Punkt, der glatt in den nicht geschnittenen Teil der Projektion übergeht, und Mittel zum Verwenden der Momente nullter und erster Ordnung enthalten, um das Polynom niedriger Ordnung zwischen dem Anfangspunkt und einem Punkt anzupassen, an dem die verlängerte Projektion Null wird.

18. Vorrichtung nach Anspruch 17, dadurch gekennzeichnet, daß das Polynom niedriger Ordnung ein Polynom erster Ordnung ist.

Revendications

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1. Procédé de compensation d'une image CT dans lequel un corps est exposé à un rayonnement selon une pluralité d'angles autour du corps, en détectant le rayonnement passant par le corps selon la pluralité d'angles pour créer un ensemble de projections dans lequel certaines des projections sont affectées par le fait que le corps s'étend au-delà du champ de visée, et dans lequel chacune des projections est associée à des informations de canal de référence, caractérisé par les étapes consistant à détecter les informations de canal de référence en dessous d'un niveau prédéterminé pour identifier les projections dans lesquelles des informations de canal de référence sont affectées par l'objet, déterminer un niveau de canal de référence typique à partir des projections non affectées, affecter le niveau de canal de référence typique aux canaux de référence des projections identifiées, normaliser chaque projection par le niveau de référence qui lui est affecté, et produire une image à partir de l'ensemble de projections normalisé.

2. Procédé selon la revendication 1, caractérisé par les étapes consistant à: trouver le niveau de canal de référence maximale dans l'ensemble de projections, identifier chaque projection ayant un niveau de canal de référence qui est d'une quantité prédéterminée inférieur audit niveau maximal, pour identifier les projections ayant des informations de canal de référence affectées par l'objet, déterminer une valeur typique du niveau de canal de référence pour les projections non identifiées, remplacer le niveau de canal de référence dans les projections identifiées par ladite valeur typique, normaliser chaque projection par rapport au niveau de référence qui lui est affecté, et produire une image à partir de l'ensemble de projections modifié.

3. Procédé selon l'une des revendications 1 ou 2 dans lequel certaines des projections sont tronquées, caractérisé en outre par les étapes consistant à: déterminer les moments d'ordre zéro et un de l'ensemble de projections, déterminer à partir du moment d'ordre zéro la quantité de masse manquante à partir des projections tronquées, déterminer à partir des moments du premier ordre le centre d'une projection étendue ayant trait à chaque projection tronquée, utiliser les informations de masse manquante et de centre pour chaque projection tronquée pour étendre ladite projection, convoluer chaque projection pour produire un ensemble de projections convoluées, et produire une image à partir de l'ensemble de projections convoluées.

4. Procédé selon la revendication 3, caractérisé en ce que l'étape de convolution comprend les étapes consistant à utiliser une transformée de Fourier rapide pour convoluer chaque projection non-tronquée et la partie non-tronquée de chaque projection tronquée, utiliser une solution de forme fermée pour convoluer les parties étendues des projections tronquées, et combiner la solution de forme fermée avec la convolution pour chaque ensemble de projections tronquées.

5. Procédé selon l'une quelconque des revendications 1 à 4, caractérisé par les étapes consistant à: déterminer une pluralité de moments de l'ensemble de projections, déterminer à partir de ces moments la quantité de masse manquante pour chaque projection tronquée et la distribution de la masse manquante dans chaque projection tronquée, adapter un polynôme d'ordre bas se conformant avec les moments et les conditions aux limites pour étendre chaque projection tronquée, convoluer chaque projection avec un noyau pour produire un ensemble de projections tronquées et produire une image à partir de l'ensemble de projections convoluées.

6. Procédé selon la revendication 5, caractérisé en ce que l'étape consistant à déterminer une pluralité de moments comprend la détermination des moments d'ordre zéro et un, l'étape de détermination de la quantité de masse manquante utilise le moment d'ordre zéro, et l'étape de détermination de la distribution de la masse manquante utilise le moment du premier ordre.

7. Procédé selon la revendication 5, caractérisé en ce que l'étape de convolution inclut l'utilisation d'une transformée de Fourier rapide pour convoluer chaque projection non-tronquée et la partie non-tronquée de chaque projection tronquée, l'utilisation d'une solution de forme fermée pour convoluer les parties étendues des projections tronquées, et la combinaison de la solution de forme fermée à la convolution pour chaque projection tronquée.

8. Procédé selon l'une quelconque des revendications 5, 6 ou 7, caractérisé en ce que l'étape d'adaptation d'un polynôme d'ordre bas comprend les étapes consistant à: faire partir la partie étendue en un point se fondant de façon lisse dans la partie non tronquée de la projection, utiliser les moments d'ordre zéro et un pour adapter le polynôme d'ordre bas entre le point de départ et un point d'arrivée pour lequel la projection étendue passe à zéro.

9. Procédé selon la revendication 8, caractérisé en ce que le polynôme d'ordre bas est un polynôme du premier ordre.

10. Appareil de compensation d'une image CT dans lequel un corps (15) exposé à un rayonnement

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selon une pluralité d'angles autour du corps, comprenant des moyens (14) pour détecter le rayonnement passant par le corps selon la pluralité d'angles pour créer un ensemble de projections dans lequel certaines des projections sont affectées par le fait que le corps s'étend au-delà du champ de visée, et dans lequel chacune des projections est associée à des informations de canal de référence (21, 22), caractérisé par des
5 moyens (32, 33, 36) de détection des informations de canal de référence en dessous d'un niveau prédéterminé pour identifier les projections dans lesquelles des informations de canal de référence sont affectées par l'objet, des moyens (41) de détermination d'un niveau de canal de référence typique à partir des projections non affectées, des moyens (43) d'affectation du niveau de canal de référence typique aux canaux de référence des projections identifiées, des moyens (44) de normalisation de chaque projection
10 par le niveau de référence qui lui est affecté, est de moyens (16, 17) de production d'image à partir de l'ensemble de projections normalisé.

11. Appareil selon la revendication 10, caractérisé par des moyens (32) pour trouver le niveau de canal de référence maximale dans l'ensemble de projections, des moyens (33, 36) pour identifier chaque projection ayant un niveau de canal de référence qui est d'une quantité prédéterminée inférieur audit
15 niveau maximal, pour identifier les projections ayant des informations de canal de référence affectées par l'objet, des moyens (41) pour déterminer une valeur typique du niveau de canal de référence pour les projections non identifiées, des moyens (43) pour remplacer le niveau de canal de référence dans les projections identifiées par ladite valeur typique, des moyens (44) pour normaliser chaque projection par rapport au niveau de référence qui lui est affecté, et des moyens (16, 17) pour produire une image à partir
20 de l'ensemble de projections modifié.

12. Appareil selon l'une des revendications 10 ou 11 dans lequel certaines des projections sont tronquées, caractérisé en outre par des moyens (73) pour déterminer les moments d'ordre zéro et un de l'ensemble de projections, des moyens (82) pour déterminer à partir du moment d'ordre zéro la quantité de
25 masse manquante à partir des projections tronquées, des moyens (83) pour déterminer à partir des moments du premier ordre le centre d'une projection étendue ayant trait à chaque projection tronquée, des moyens (84, 85) pour utiliser les informations de masse manquante et de centre pour chaque projection tronquée pour étendre ladite projection, des moyens (90, 92) pour convoluer chaque projection pour produire un ensemble de projections convoluées, et des moyens (93) pour produire une image à partir de
l'ensemble de projections convoluées.

13. Appareil selon la revendication 12, caractérisé en ce que les moyens de convolution comprennent des moyens (90) pour utiliser une transformée de Fourier rapide pour convoluer chaque projection non-tronquée et la partie non-tronquée de chaque projection tronquée, des moyens (91) pour utiliser une
30 solution de forme fermée pour convoluer les parties étendues des projections tronquées, et des moyens (92) pour combiner la solution de forme fermée avec la convolution pour chaque ensemble de projections tronquées.

14. Appareil selon l'une quelconque des revendications 10 à 13, caractérisé par des moyens (73) pour déterminer une pluralité de moments de l'ensemble de projections, des moyens (82, 83) pour déterminer à partir de ces moments la quantité de masse manquante pour chaque projection tronquée et la distribution de la masse manquante dans chaque projection tronquée, des moyens (85) pour adapter un polynôme
40 d'ordre bas se conformant avec les moments et les conditions aux limites pour étendre chaque projection tronquée, des moyens (90, 92) pour convoluer chaque projection avec un noyau pour produire un ensemble de projections tronquées et des moyens (93) pour produire une image à partir de l'ensemble de projections convoluées.

15. Appareil selon la revendication 14, caractérisé en ce que les moyens pour à déterminer une pluralité de moments comprennent des moyens (73) de détermination des moments d'ordre zéro et un, les
45 moyens (82) pour déterminer la quantité de masse manquante utilisent le moment d'ordre zéro, et les moyens (83) pour déterminer la distribution de la masse manquante utilisent le moment du premier ordre.

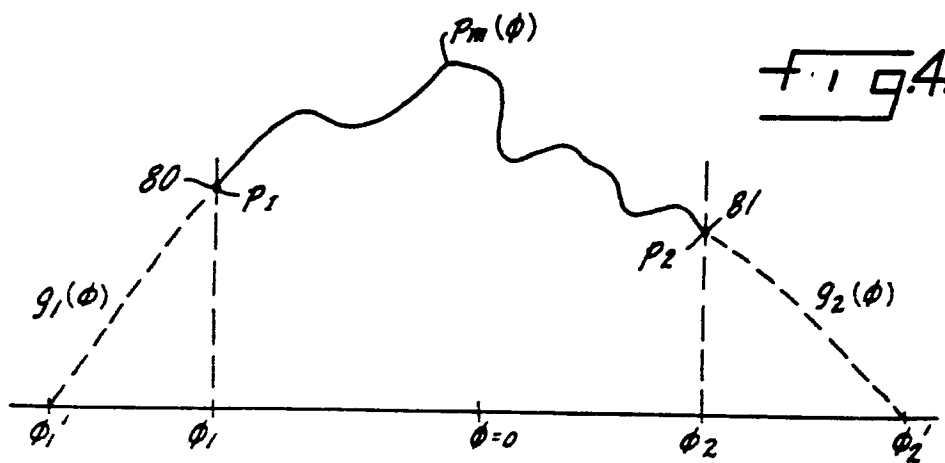
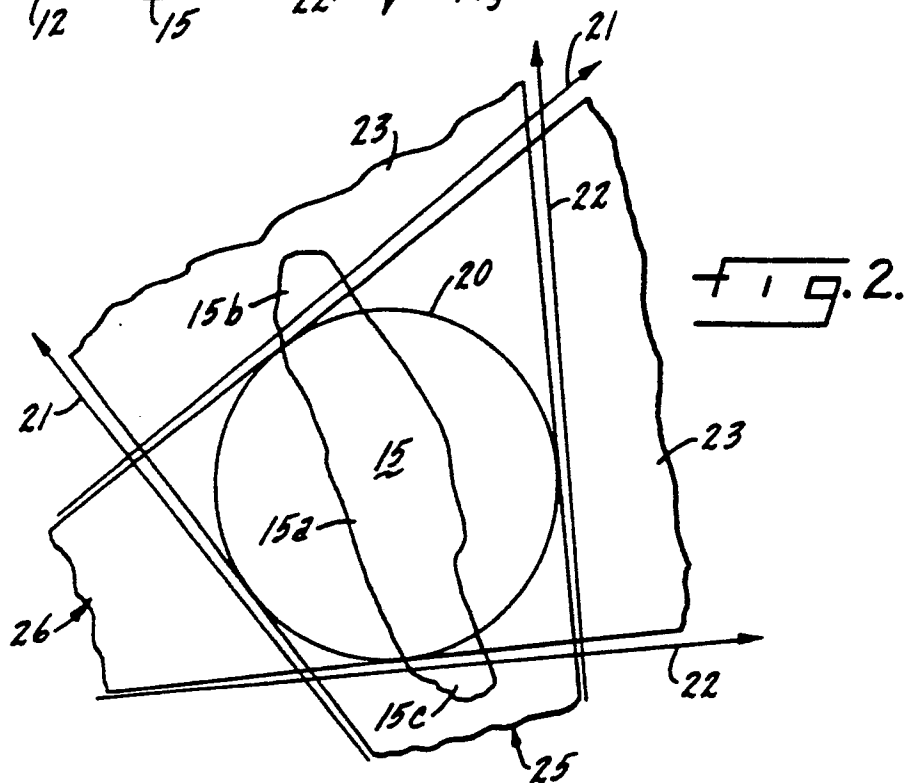
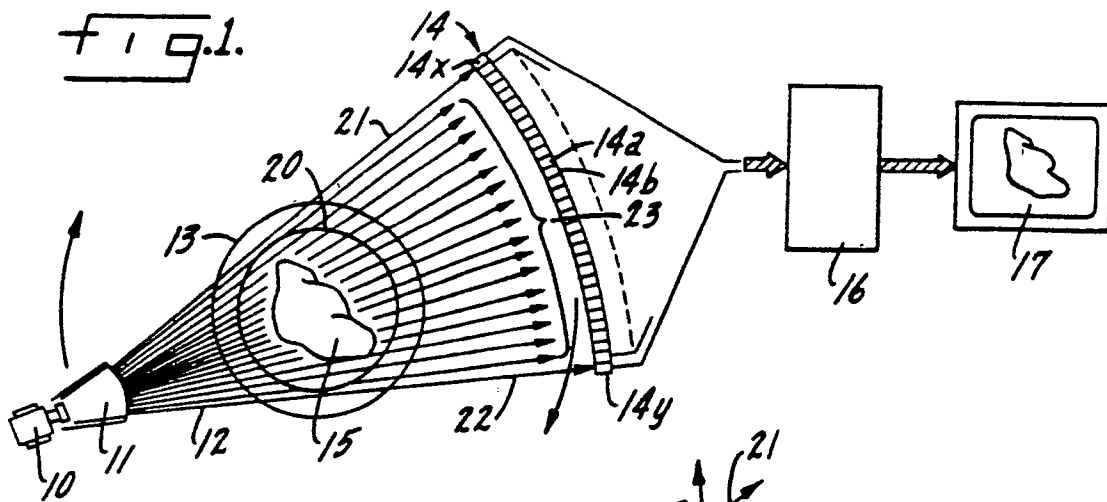
16. Appareil selon la revendication 14, caractérisé en ce que les moyens de convolution incluent des moyens (90) pour utiliser une transformée de Fourier rapide pour convoluer chaque projection non-tronquée et la partie non-tronquée de chaque projection tronquée, des moyens (91) pour utiliser une
50 solution de forme fermée pour convoluer les parties étendues des projections tronquées, et des moyens (92) pour combiner la solution de forme fermée à la convolution pour chaque projection tronquée.

17. Appareil selon l'une quelconque des revendications 14 à 16, caractérisé en ce que les moyens (85) d'adaptation d'un polynôme d'ordre bas comprennent des moyens pour faire partir la partie étendue en un
55 point se fondant de façon lisse dans la partie non tronquée de la projection, des moyens pour utiliser les moments d'ordre zéro et un pour adapter le polynôme d'ordre bas entre le point de départ et un point d'arrivée pour lequel la projection étendue passe à zéro.

18. Appareil selon la revendication 17, caractérisé en ce que le polynôme d'ordre bas est un polynôme du premier ordre.

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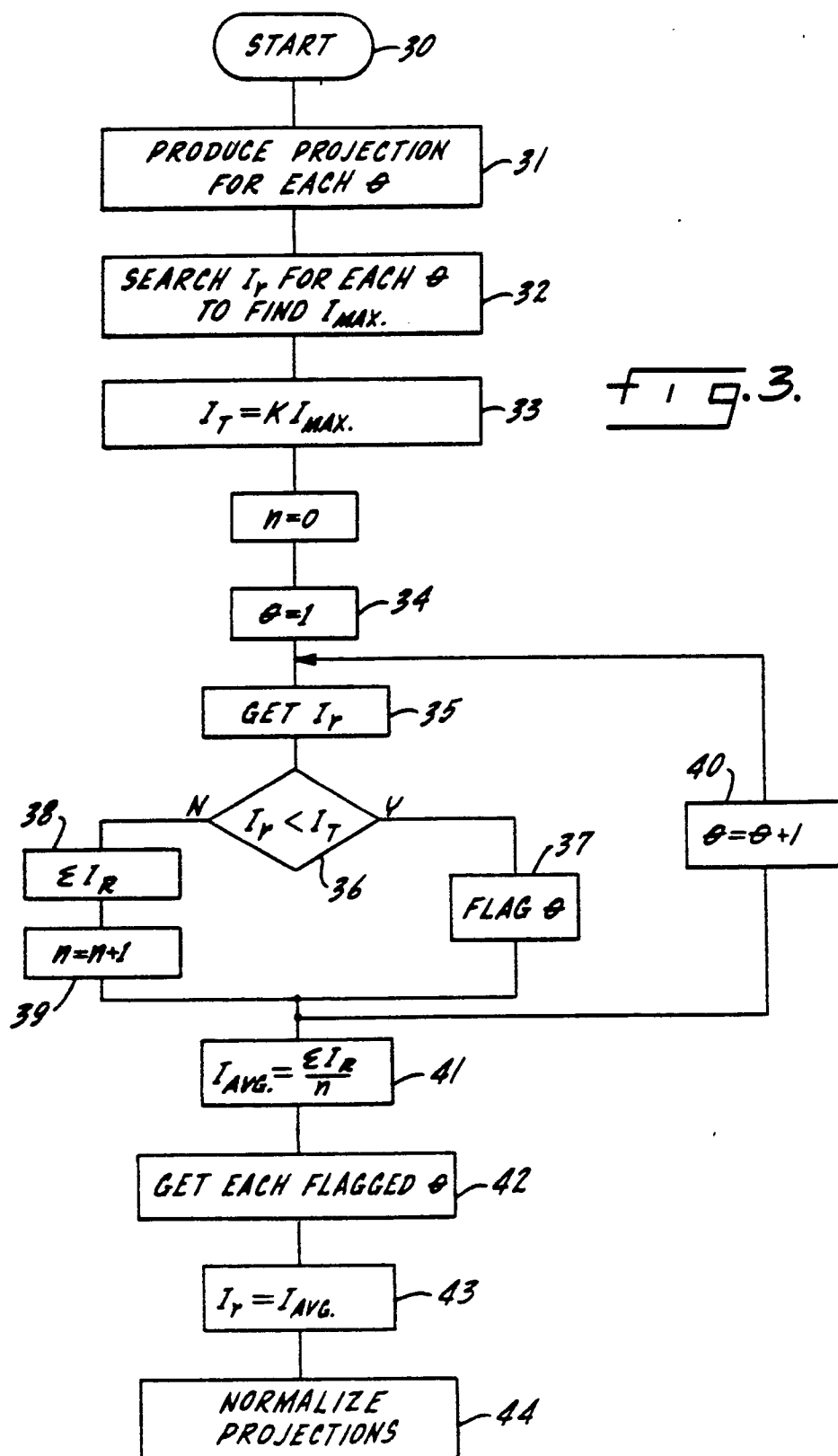
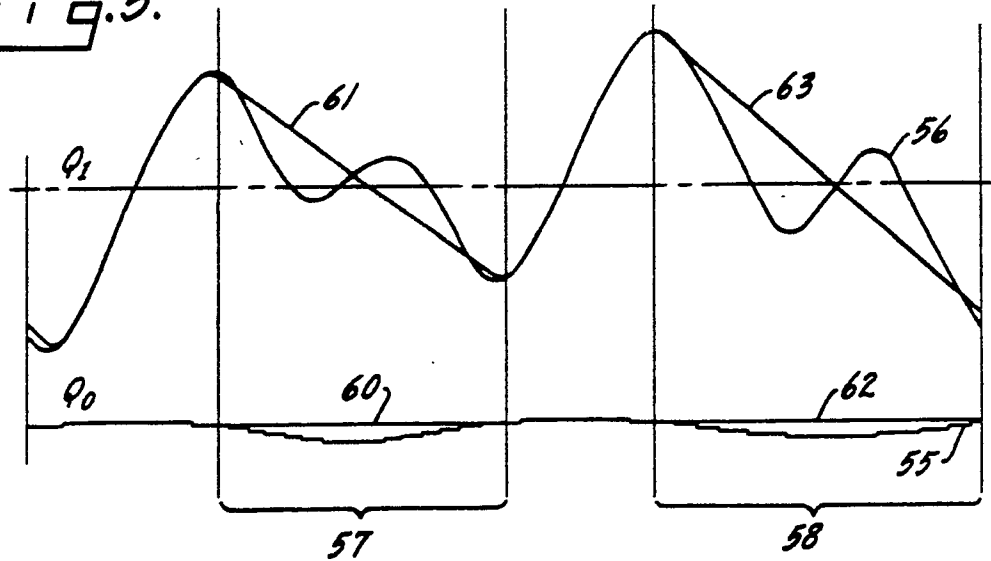


Fig. 5.



START

Fig. 6A.

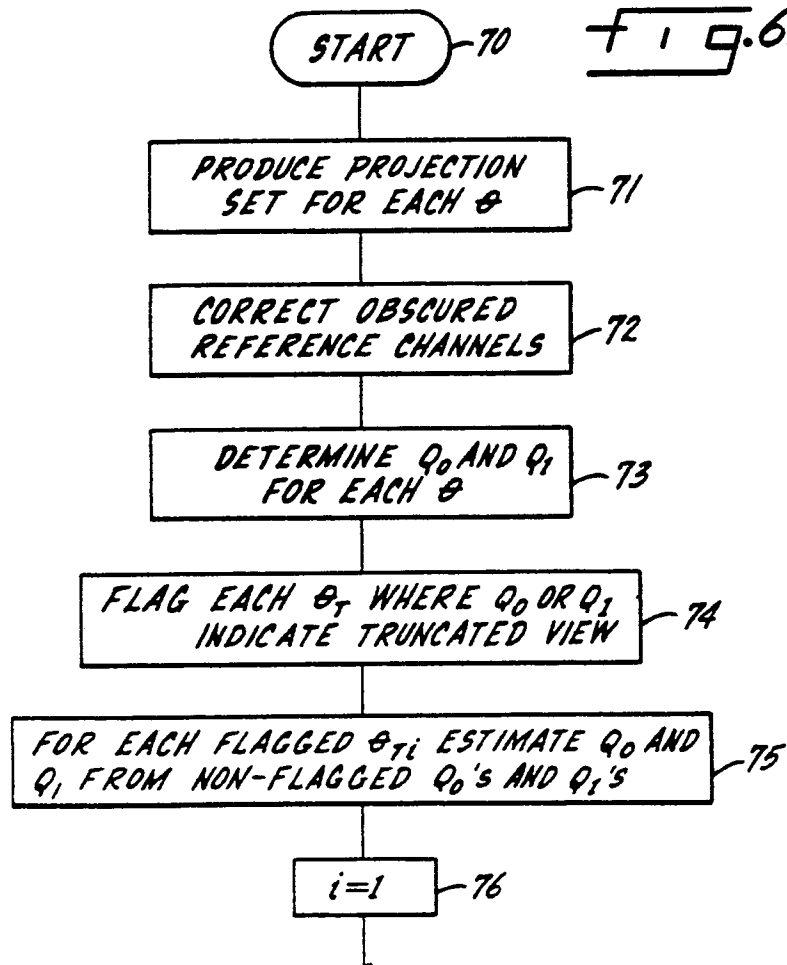


Fig. 6B.

